Shaft crack detected at an ammonia plant

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The Incitec (formerly Austral Pacific Fertilizers) Ammonia Plant is situated on Gibson Island on the Brisbane River in Queensland, Australia. The Plant was built in 1969 by J.F. Pritchard of Kansas, with Cooper Bessemer main compressors and Worthington steam turbines and pumps.

In 1989, during a major plant turnaround, all critical machines were retrofitted with Bently Nevada radial vibration probes, Keyphasors and axial displacement probes connected to 7200 System Monitors. A Bently Nevada Dynamic Data Manager® (DDM) was also installed to provide continuous monitoring of the 7200 System. Additionally, all critical machine bearings were fitted with thermocouples connected to a Bently Nevada Process Data Manager. The whole retrofitting project was carried out by Incitec's Engineering and Maintenance staff, with specialized assistance by Rotor Dynamics Pty. Ltd., the Australian representative of Bently Nevada.

Cracked shaft on C602 Syn Gas Compressor

The Synthesis Gas Compressor, C602, is the most critical machine in the petrochemical complex. It's configuration (Figure 1) is unusual in that a steam turbine driver is not employed. Instead, the compressor train is driven by a Pratt and Whitney GG4A-2 gas generator exhausting into a Cooper Bessemer, 18,000 HP reaction turbine (RT). The RT drives three Cooper Bessemer centrifugal "barrel type" compressors through a General Electric speed increasing gearbox. The gearbox suffered two major failures in 1986. Since being fitted with a new set of Westech gears in 1987, however, it has performed reliably.

The first indication of a problem on C602 occurred in early October 1991 as an increase in Direct vibration from 0.2 to 0.8 mils (5.1 to 20.3 μm) on the casing-mounted seismic transducer of the RT. The increase was noticed by plant operators over the long weekend and was subsequently reported to the plant engineer at 7:00 a.m. on the following Tuesday.

Unfortunately, all but one of the four Bently Nevada radial proximity probes on the RT had been damaged some time previously as a result of an oil fire in the bearing house tunnel. Thus, only limited information was available on the DDM. The single probe that was functioning, however, indicated a small increase in the overall level. Readings taken with a portable unit confirmed that the casing readings were genuine.

As the overall levels were still very low, no DDM alarms had been activated. A thorough check of all the other points on the train was, nevertheless, carried out. A small increase was noted on the vertical probe of the drive end of the input shaft on the gearbox (Figure 2). This increase was not evident on the horizontal probe (Figure 3). Further analysis of the vertical probe showed that all the vibration was occurring at 1X, and there had been a significant change in the phase angle. This change in phase angle was confirmed on the horizontal probe (Figures 4 and 5). This initial vibration data provided by the DDM gave early signs of a changing system. The ability to generate Polar Trend plots was extremely useful in explaining what appeared to be happening on this very critical machine (Figures 6 and 7).►

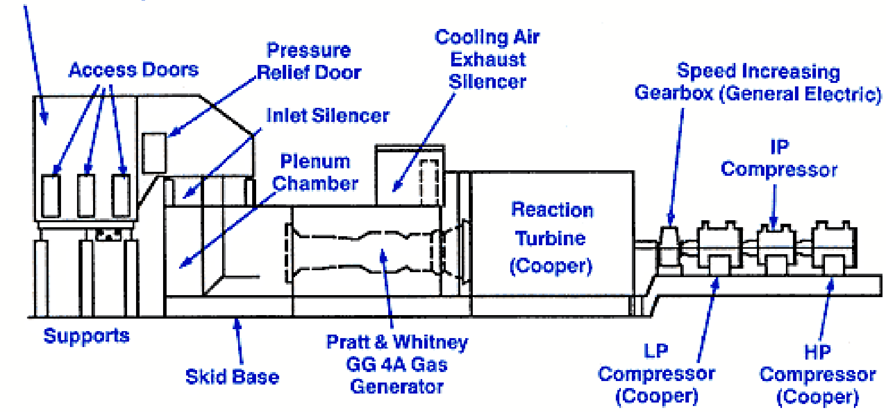

Figure 1
Gas turbine compressor unit outline.

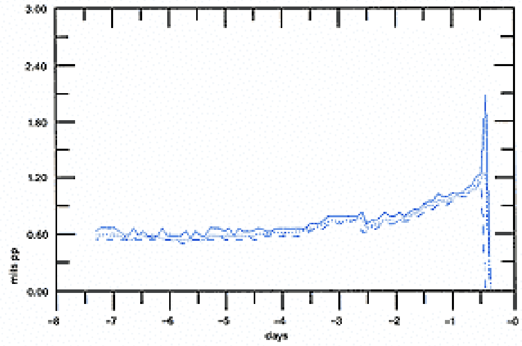

Figure 2
Overall vibration Trend for vertical probe on drive end of gearbox input shaft showing small increase prior to failure.

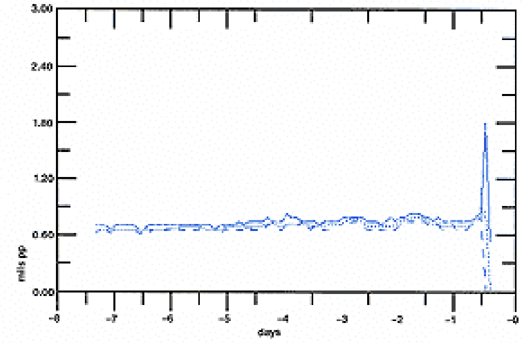

Figure 3
Overall vibration Trend for horizontal probe on drive end of gearbox input shaft was steady prior to failure.

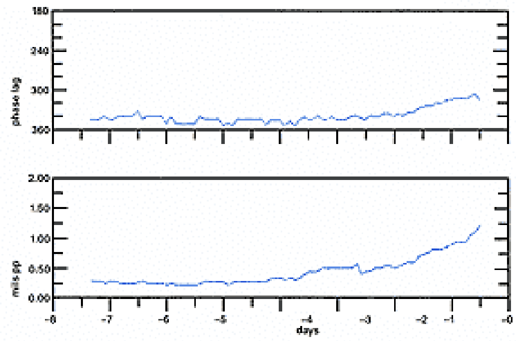

Figure 4
1 Week Trend plot of increasing 1X amplitude and changing phase angle for the vertical probe.

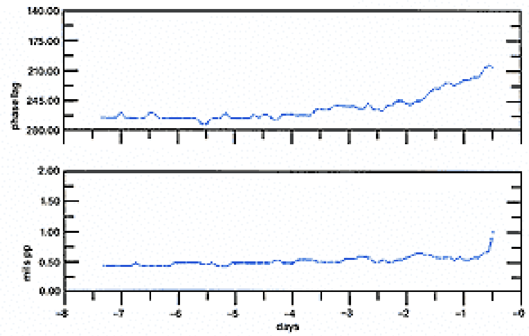

Figure 5
1 Week Trend plot increasing 1X amplitude and changing phase angle for the horizontal probe.

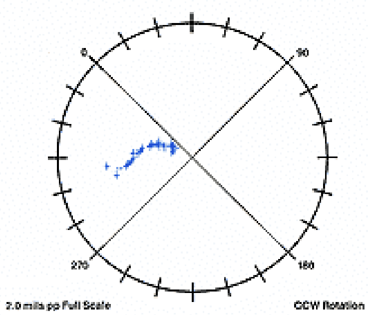

Figure 6
1X Polar Trend plot for the vertical probe.

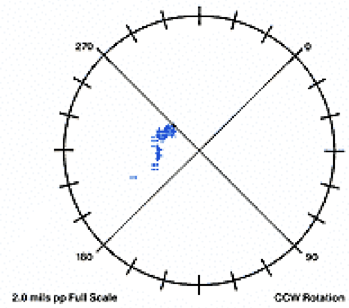

Figure 7
1X Polar Trend plot for the horizontal probe.

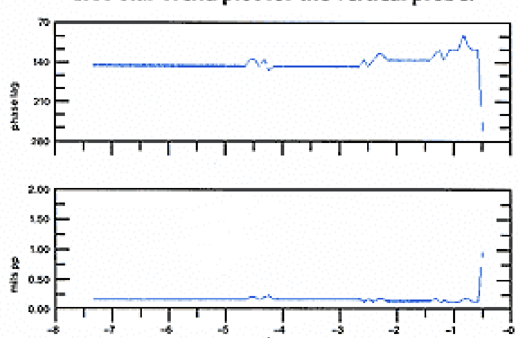

Figure 8
1 Week Trend plot of dramatic change in 2X phase angle and increase in amplitude for the vertical probe.

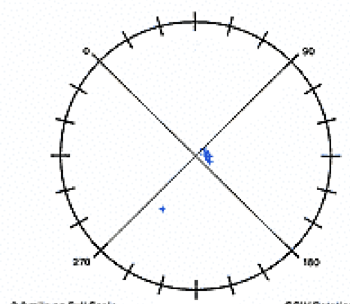

Figure 9
2X Polar Trend plot for the vertical probe.

One of the maintenance supervisors remembered that C602 had been shut down in 1972 because of high vibration on the RT. The fault was eventually traced to a crack on the four-foot-long coupling between the RT and the gearbox. As the crack in 1972 was at the RT end of the coupling, it was assumed that a similar event could be reoccurring. This would explain why the primary indication of vibration had been picked up on the RT seismic transducer, and the gearbox end of the coupling was showing a change in phase angle on the DDM.

By the time this preliminary diagnosis had been reached, it was 10:00 a.m. To overcome the lack of data at the RT, operators decided to measure phase angle at either side of the coupling with the portable vibration measuring equipment available. During the next two hours, while the portable equipment was set up and the measurements were taken, the vibration level on the RT casing increased from 0.8 to 1.2 mils (20.3 to 30.5 μm). The drive end of the gearbox input shaft remained steady at 1.2 mils (30.5 μm) as measured on the DDM. Unfortunately, the vibration readings taken with the hand-held instruments on the RT and the gearbox did not provide phase information and were therefore halted.

At around 12:30 p.m., just as the Plant Engineer and the Operations Superintendent were monitoring a slight reduction in the vibration level on the RT, there was a significant step change on the drive end of the gearbox input shaft. The vibration level suddenly increased from 1.2 to 2 mils (30.5 to 50.8 μm). A very strong 2X component of about 1 mil (25.4 μm) had suddenly appeared. Previously, there had only been a 1X component of approximately the same magnitude. The 2X phase angle was immediately checked, and it had moved from 115 to 260 degrees (Figure 8). The dramatic change in phase angle is very clearly demonstrated by the 2X Polar Trend plot (Figure 9).

The machine was shut down immediately, as the available information indicated that a shaft crack was highly likely. Ammonia and downstream production was halted. As soon as the machine was cool enough, and the oil was turned off, the coupling was opened for inspection. The coupling was subsequently found to be in very good condition, as was the rotor of the RT. It was not until six hours later, when the coupling had been removed from the drive end of the gearbox input shaft, that a crack was found.

The crack appeared to have started at the keyway of the coupling taper and had propagated 180 degrees around the shaft (Figures 10-12). Subsequent ultrasonic checks showed the crack had actually penetrated 2.2 inches (55mm) into the shaft at the coupling taper, which at that point was about 5.3 inches (135mm) in diameter.

Very clearly, with 18,000 HP transmitted through the gearbox, the complete failure of the input shaft was imminent. However, by successfully providing an early warning of the developing crack, the DDM allowed the Syn Gas Compressor to be safely shut down. Once the crack was found, the spare set of gears was installed, and full plant production resumed within four days. ■

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Don Silcock is originally from England where, from 1973 to 1977, he worked as a Service Engineer for the Turbocompressor Division of Sulzer Bros.

From 1977 to 1983, he worked on the ammonia plants at Marsa El Brega in Libya, then spent a year in Saudi Arabia on the Aramco East/West crude oil pipeline. From 1984 to 1991, he worked on the ammonia/methanol plants in Bahrain.

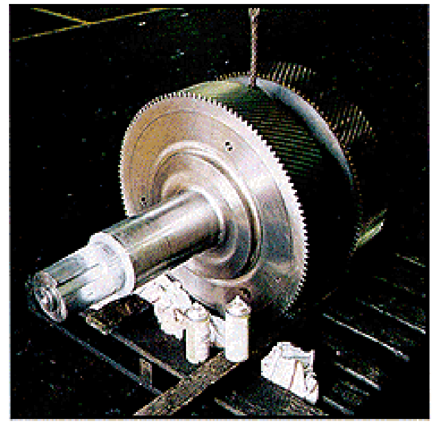

Figure 10
The bull gear component showing the location of the keyway.

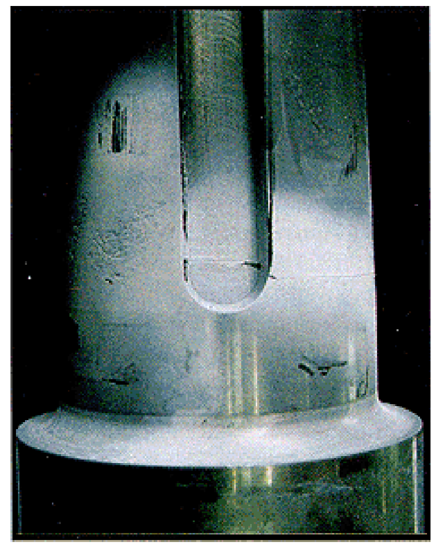

Figure 11
Detail showing the crack location in relation to the keyway.

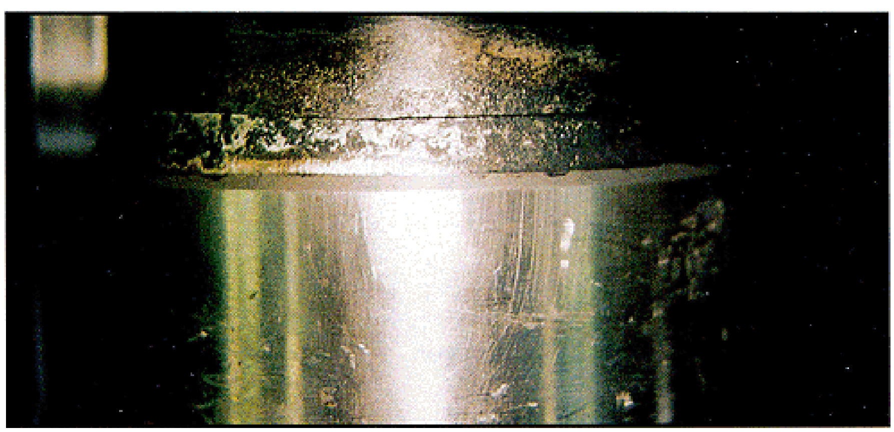

Figure 12
Detail showing fretting, corrosion and crack location.